

Lewis



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REPLY TO  
ATTN OF: GP

DEC 27 1973

TO: KSI/Scientific & Technical Information Division  
Attention: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General Counsel for  
Patent Matters

SUBJECT: Announcement of NASA-Owned U.S. Patents in STAR

In accordance with the procedures agreed upon by Code GP  
and Code KSI, the attached NASA-owned U.S. patent is being  
forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U.S. Patent No. : 3,777,200  
Government or  
Corporate Employee : Government  
Supplementary Corporate  
Source (if applicable) : ~  
NASA Patent Case No. : LEW-11,162-1

NOTE - If this patent covers an invention made by a corporate  
employee of a NASA Contractor, the following is applicable:

Yes ☐ No ☒

Pursuant to Section 305(a) of the National Aeronautics and  
Space Act, the name of the Administrator of NASA appears on  
the first page of the patent; however, the name of the actual  
inventor (author) appears at the heading of column No. 1 of  
the Specification, following the words ". . . with respect to  
an invention of . . ."

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Enclosure

Copy of Patent cited above



(NASA-Case-LEW-11162-1) HIGH POWERED ARC  
ELECTRODES Patent (NASA) 8 p CSC 09E

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24226

N74-12913

[54] **HIGH POWERED ARC ELECTRODES**

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[22] Filed: **May 14, 1971**

[21] Appl. No.: **143,508**

[52] U.S. Cl. .... **313/32, 313/153, 313/209,  
313/217, 313/224**

[51] Int. Cl. .... **H01J 17/04**

[58] Field of Search .... **313/30, 32, 37, 209,  
313/211, 217, 184, 224, 341**

[56] **References Cited**

**UNITED STATES PATENTS**

3,073,984 1/1963 Eschenbach et al. .... 313/30

1,055,003	3/1913	Wagener .....	313/32
2,239,416	4/1941	Ehrenberg .....	313/37
2,887,603	5/1959	Haidinger .....	313/211
2,179,929	11/1939	Hansell .....	313/30
3,405,305	10/1968	Winzeler et al. ....	313/30
3,474,278	10/1969	Thouret et al. ....	313/30
3,531,673	9/1970	Paquette .....	313/32

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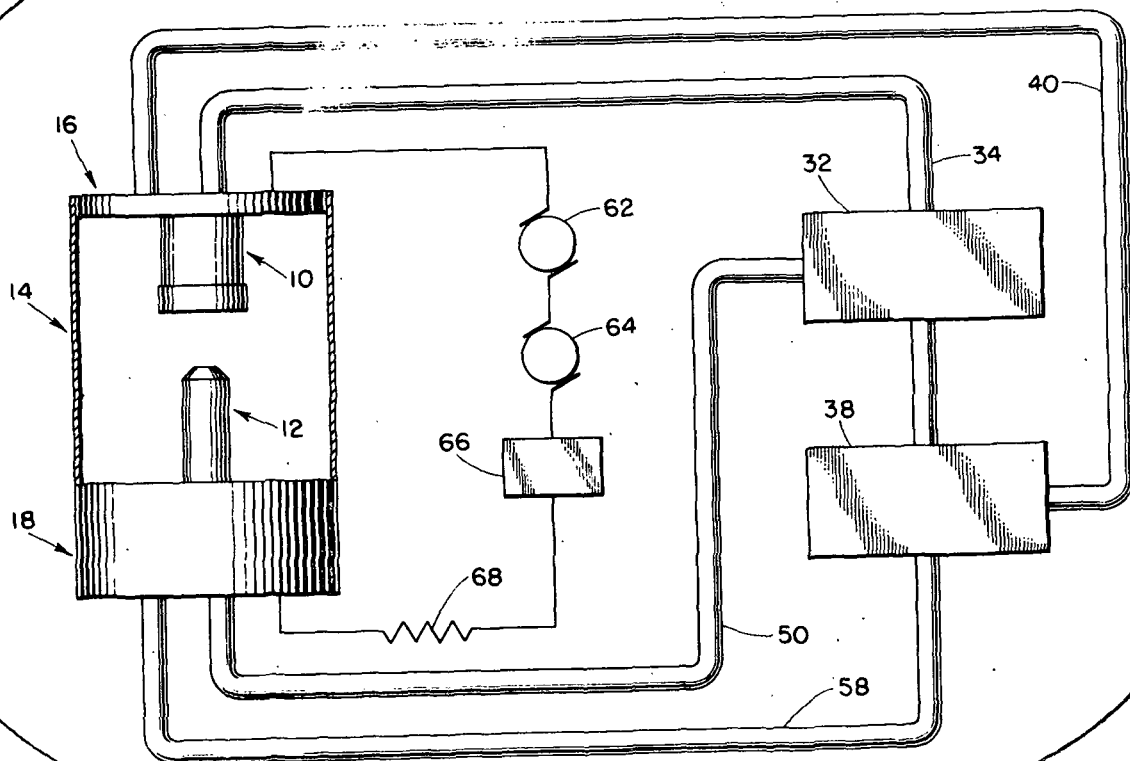
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[57] **ABSTRACT**

Nonconsumable metal electric arc electrodes capable of being operated in a variety of gases at various pressures, current, and powers. The cathode has a conical annulus tip to spread the emission area and provide cooling.

**13 Claims, 8 Drawings**



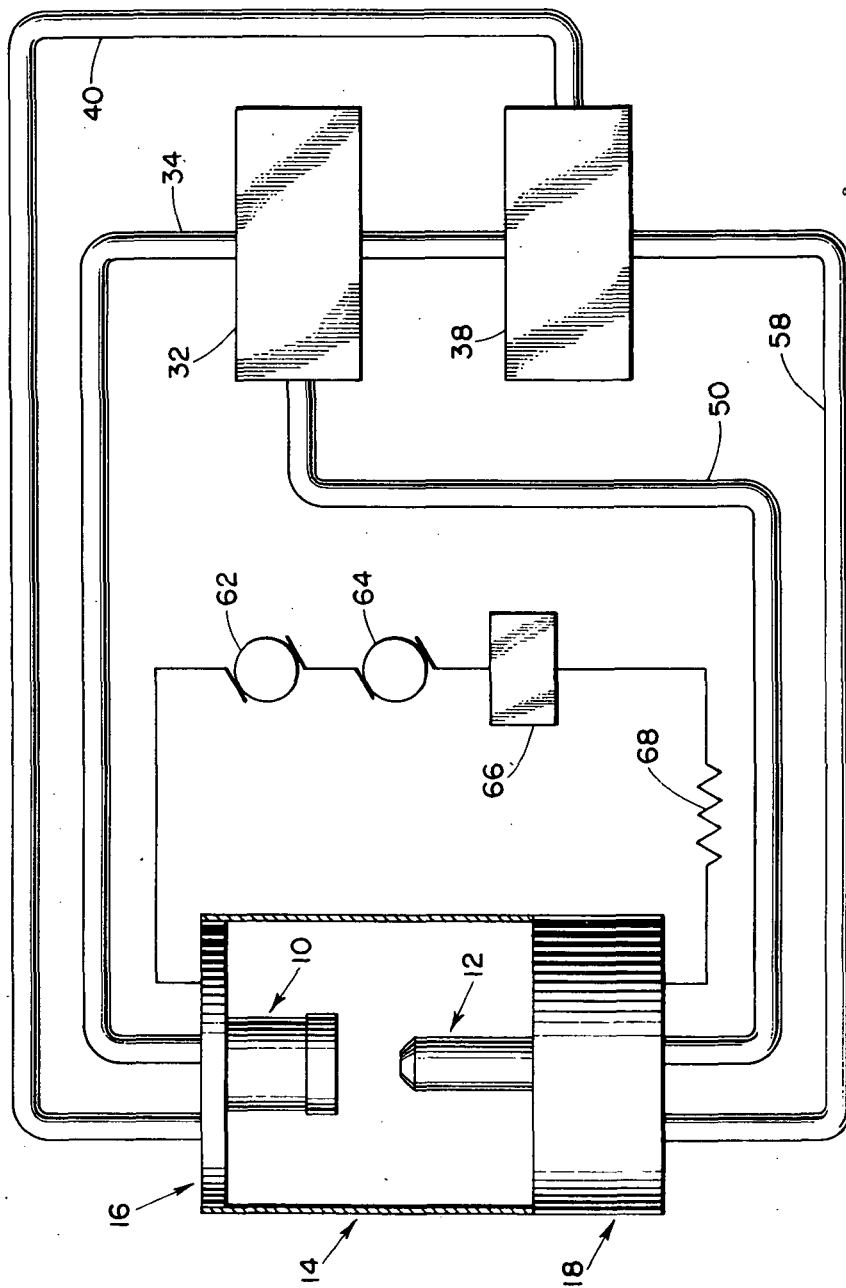


FIG. 1

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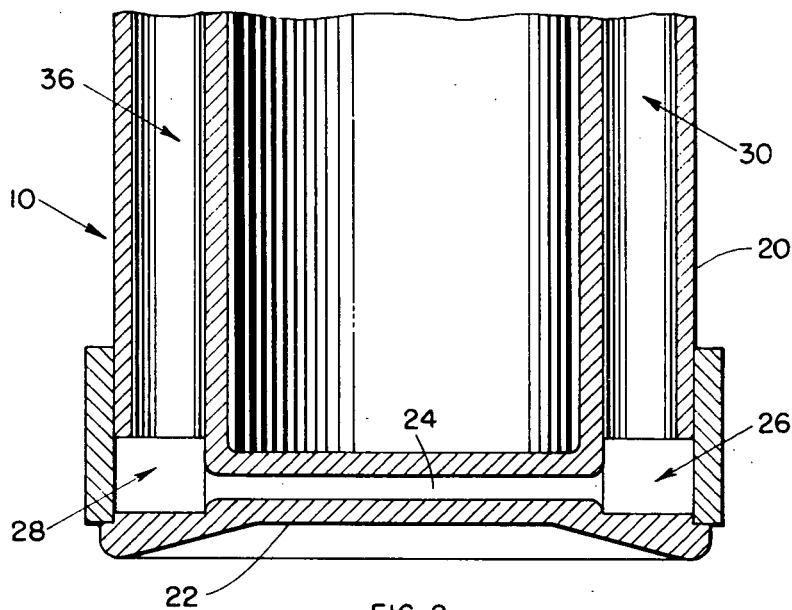


FIG. 2

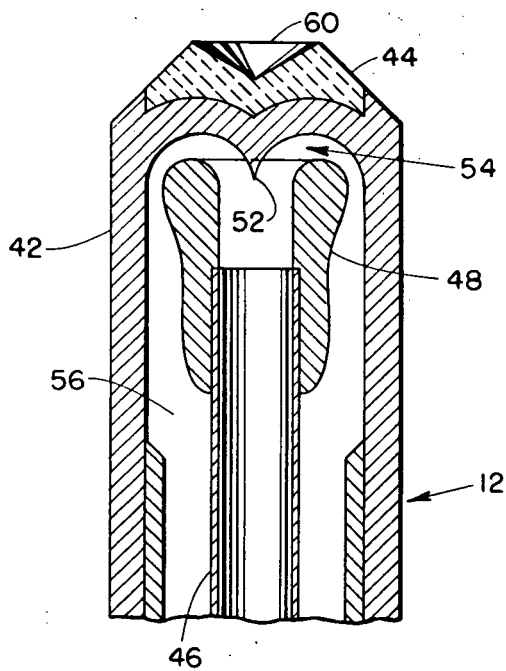


FIG. 3

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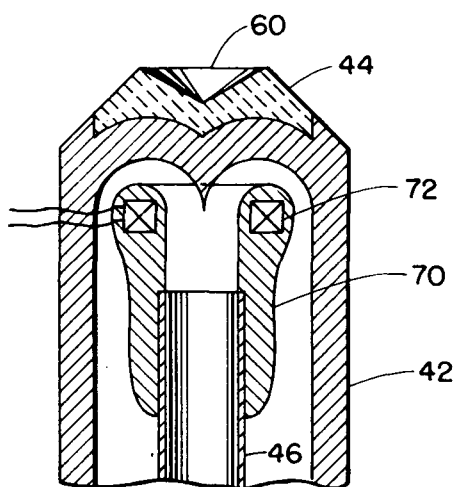


FIG. 4

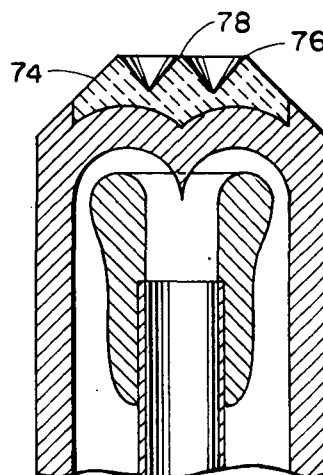


FIG. 5

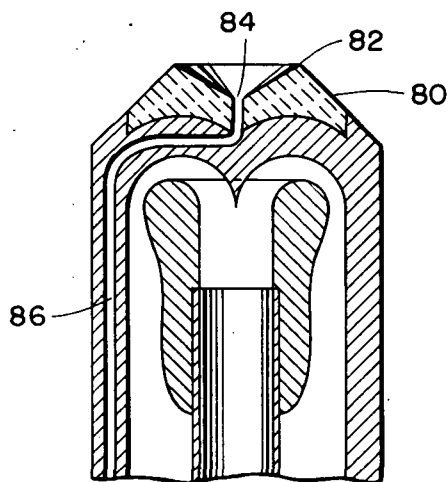


FIG. 6

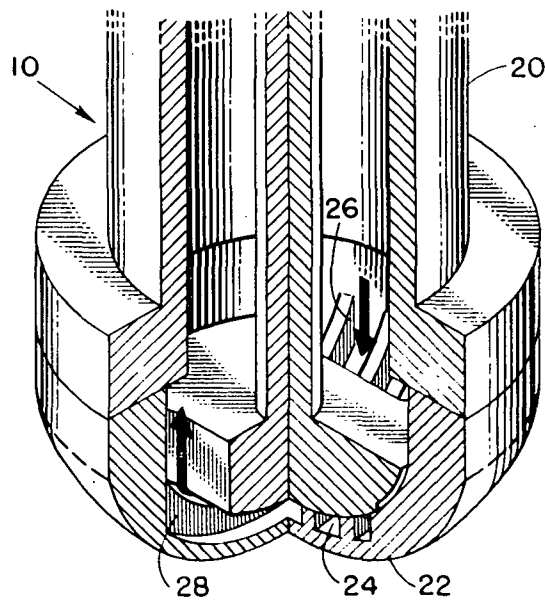
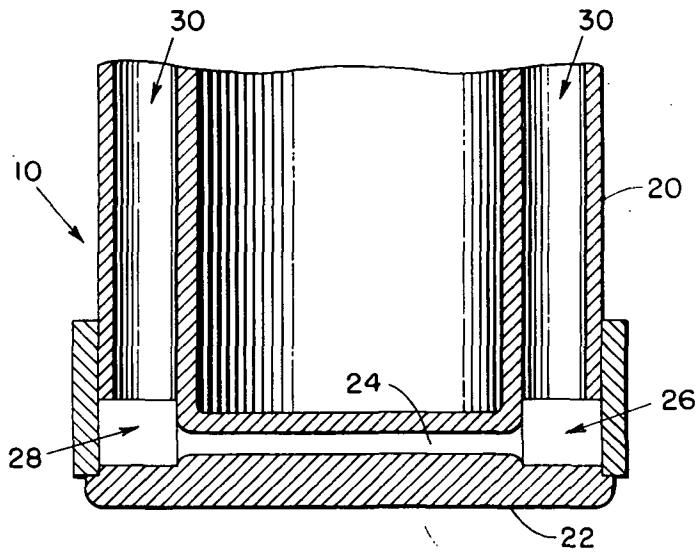
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SHEET 4 OF 4



## HIGH POWERED ARC ELECTRODES

### ORIGIN OF THE INVENTION

The invention described herein was made by employees of the United States Government and may be manufactured and used by or for the Government for governmental purposes without the payment of any royalties thereon or therefor.

### BACKGROUND OF THE INVENTION

This invention is concerned with a high power, free-burning electric arc which forms the radiation source for a solar simulator. The invention is particularly directed to improved electrodes capable of extended life and clean operation.

Various types of electrodes are used to produce electric arcs. Consumable carbon electrodes are used with many types of arcs. Compact arc lamps which utilize less than 20 kilowatts employ radiation cooled, non-consumable metal electrodes. Compact arc lamps in the 20 to 40 kilowatt range employ water cooled metal nonconsumable electrodes. Still higher power lamps greater than 50 kilowatts have similar electrodes in addition to a moving gas which provide useful lives of several hours.

Some electrodes have short lives while others are not economical to operate. The consumable electrodes require periodic replacement. Only a limited amount of illumination can be expected from some low powered lamps.

A solar simulator uses an arc as the radiation source. This arc must be positioned precisely and maintained stable with respect to an optical collector. Electrodes for the arc must be capable of high power operation. Evaporation of the electrodes must be small to minimize the deposition of electrode material on optical surfaces.

### SUMMARY OF THE INVENTION

These problems have been solved by using nonconsumable metal electric arc electrodes in accordance with the present invention. The anode contains a number of small diameter passages for carrying a liquid coolant at high flow velocities. The cathode is likewise liquid cooled and its structure reduces the local heat load which must be conducted through the tip to the cooling liquid. A circular annulus tip on the cathode spreads the emission area from a concentrated spot to a continuous or intermittent line. The emission from all portions of this line occurs simultaneously.

### OBJECTS OF THE INVENTION

It is, therefore, an object of the present invention to provide nonconsumable electrodes that are capable of being operated at high power.

Another object of the invention is to provide nonconsumable metal electric arc electrodes having longer lives for use in a solar simulator.

A further object of the invention is to provide electrodes that are capable of being scaled for the most efficient operation under various conditions.

These and other objects of the invention will be apparent from the specification that follows and from the drawing wherein like numerals are used throughout to identify like parts.

### DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic view of a portion of a solar simulator constructed in accordance with the present invention;

FIG. 2 is an enlarged vertical section view of an anode utilized in the apparatus shown in FIG. 1;

FIG. 3 is an enlarged vertical section view of a cathode utilized in the apparatus shown in FIG. 1;

FIG. 4 is an enlarged vertical section view of an alternate embodiment of the cathode shown in FIG. 3 which includes apparatus for generating a magnetic field;

FIG. 5 is an enlarged vertical section view of an alternate embodiment of the cathode as shown in FIG. 3 having an annulus with a raised center point;

FIG. 6 is an enlarged vertical section view of an alternate embodiment of the cathode shown in FIG. 3 having a provision for the admission of a cooling gas to the center of the arc;

FIG. 7 is an enlarged vertical section view of an alternate embodiment of the anode shown in FIG. 2; and

FIG. 8 is an enlarged quarter section view of still another alternate embodiment of the anode utilized in the apparatus shown in FIG. 1.

### DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawing there is shown in FIG. 1 a pair of electrodes constructed in accordance with the present invention. These electrodes are used to form the arc of a solar simulator.

Each electrode pair comprises an anode 10 and a cathode 12 positioned in a housing 14 that is filled with a suitable inert gas, such as argon, krypton, or xenon. The anode 10 is rigidly mounted to a base 16. The cathode 12 is supported by suitable mechanism 18 for reciprocable movement toward and away from the anode 10. The mechanism 18 enables the cathode 12 to be moved into contact with the anode 10 to initiate an arc by the passage of a short circuit current through the electrodes. The mechanism 18 further enables the cathode 12 to be separated from the anode 10 a predetermined distance when the current is increased to the operating value.

The anode 10 has a cylindrical body 20 of high conductivity copper. It is also contemplated that the anode 10 can be fabricated from refractory metals, such as tungsten and molybdenum, or from alloys of these metals.

As shown in FIG. 2 an end surface 22 of the body 20 which is directed towards the cathode 12 is slightly concave. The surface 22 is smooth to avoid constriction of the arc attachment. A plurality of parallel conduits 24 are adjacent to the surface 22. The conduits 24 are in communication with an intake manifold 26 and exhaust manifold 28. Each of these manifolds extends about approximately one-half the periphery of the body 20.

Supply passages 30 extend along one side of the body 20 parallel to the axis of the anode 10. One end of each supply passage 30 is in communication with the intake manifold 26 while the opposite end is connected to a suitable coolant source 32 such as water pressurized to about 1000 psi through a supply line 34.

Discharge passages 36 extend along the opposite side of the body 20 as shown in FIG. 2. One end of each discharge passage 36 is in communication with the ex-

haust manifold 28 while the opposite end is in communication with a suitable coolant cooling device 38 through an exhaust line 40 as shown in FIG. 1.

Each cooling conduit 24 preferably has a small diameter on the order of about one-fourth inch or less. It is contemplated that internal rifling may be utilized to increase the heat transfer through a thin wall structure. Conduits 24 in the form of tubes having thin walls capable of withstanding high internal coolant pressures have been successfully used. A high pressure is necessary to raise the saturation temperature of the cooling liquid and to cause high flow velocities which is the requirement for high heat transfer.

The cathode 12 has a cylindrical body 42 which supports a cap 44 as shown in FIG. 3. The body 42 is preferably copper while the cap 44 is thoriated tungsten. The copper body 42 is vacuum cast directly to the thoriated tungsten cap 44. This eliminates the customary uncertainties encountered when making an indirect bond.

A tube 46 extends along the axis of the cylindrical body 42 toward the cap 44. A flow divider 48 is mounted on the end of the tube 46. The opposite end of the tube 46 is placed in communication with the coolant source 32 through a supply line 50 as shown in FIG. 1.

The coolant passes through the tube 46 toward the cap 44 and strikes a fin 52 in the center of the body 42. This serves to divide the flow of coolant through a constant area channel 54 adjacent the cap 44. The coolant then passes through an annular passage 56 where it flows into a discharge line 58 connected to the cooling device 38. The coolant flow passages inside the cathode 12 are plated with a less chemically active metal, such as gold, to resist deposits from the coolant thereby reducing the problem of low thermal conductivity resulting from such deposits.

The curved water passage 54 and central fin 52 reduce the local heat load to the coolant by increasing the area over which the cathode heat load enters the coolant. The constant cross sectional area of the passage 54 ensures a high heat transfer coefficient over the entire cathode cooling surface.

An important feature of the invention is the provision of a v-shaped crater 60 in the cap 44. The crater 60 creates an annular cathode from the molten annulus which forms near the rim of the crater 60 when the arc is running.

In operation, the cathode 12 is moved into contact with the anode 10 by the mounting mechanism 18. An arc is struck by passing a short circuit current of about 350 amperes through the electrodes. This current is supplied by two direct current generators 62 and 64 connected to a continuously variable voltage control 66. The generators 62 and 64 have the capacity of supplying from 0 to 500 volts. A ballast resistor 68 is connected in series with the electrodes.

After the arc is struck, the cathode 12 is separated from the anode 10 for a distance of about 3 inches. The arc spreads over the crater 60 and forms a molten annulus near the rim. The area of attachment of the arc to the cathode 12 is larger than on conventional cathode tips. This larger area of attachment reduces the local heat load.

The emission from the cathode 12 can spread along the rim of the crater 60 before design operating power is reached. Emission increases strongly with increasing

temperature. The rim of the crater 60 is the least cooled part of the cap 44 causing simultaneous emission to occur from a ring or line near the rim.

The local heat load limits the current density and electrical power at which an electrode operates effectively. Effective operation is operation without excessive boiling off or melting of the emitting material, or boiling burnout occurring on the water cooled side. If the requirements exceed the effective operating condition for one electrode then multiple electrodes operating in parallel must be employed. This annular configuration is analogous with multiple electrodes in the form of an infinite number of cathodes arranged in a circle.

Electrodes constructed in accordance with the invention have been operated for 40 hours between 200 kilowatts and 400 kilowatts in argon. The average pressure of the arc ranged between 2 and 8 atmospheres. The current ranged between 2,600 amperes and 4,000 amperes.

#### DESCRIPTION OF ALTERNATE EMBODIMENTS

Referring now to FIG. 4 there is shown an alternate embodiment of a cathode utilized in the apparatus shown in FIG. 1. This cathode has a flow divider 70 mounted on the centrally disposed tube 46. The configuration of the flow divider 70 is the same as that of the flow divider 48 as shown in FIG. 3.

A direct current magnetic field generating device 72 is contained in the flow divider 70. The magnetic field generating device 72 controls the rotation of the spot arc emission about the tip of the annulus 60.

It is contemplated that a similar rotating magnetic field producing device can be mounted inside the hollow anode. In this embodiment the arc attachment area is rotated to reduce the dwell of the arc foot and the local heat load on the anode.

The cathode shown in the embodiment of FIG. 5 utilizes a cap 74 having an annulus 76 with a raised center point 78. This embodiment combines line and spot emission.

The cathode shown in FIG. 6 has a cap 80 with a crater or annulus 82. An opening 84 is provided in the center of the crater 82. A passage 86 has one end in communication with the opening 84 and the opposite end connected to a source of inert cooling gas. In this embodiment the inert gas is injected into the center of the arc through the center of the annulus.

While the preferred embodiment as well as several alternate embodiments of the invention have been shown and described, it is contemplated that other structural modifications may be made without departing from the spirit of the invention or scope of the subjoined claims. By way of example it is contemplated that the end surface 22 of the anode 10 may be flat as shown in FIG. 7 or convex as shown in FIG. 8 as well as concave.

What is claimed is:

1. Apparatus for producing an arc for a radiation source in a solar simulator comprising,
  - a rigidly mounted copper anode having an outwardly directed end surface,
  - a copper cathode mounted for reciprocal movement toward and away from said anode for initiating and adjusting the arc,
  - a housing enclosing said anode and said cathode, said housing being filled with an inert gas,



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means for passing an electric current through said anode and cathode to maintain said arc, and a thoriated tungsten cap bonded to the end of said cathode, said cap having a crater facing the end surface of said anode for forming an annulus whereby the emission area of said cathode is spread from a concentrated spot to a line with emission from all portions of said line occurring simultaneously.

2. Apparatus as claimed in claim 1 including a raised central portion within the annulus.

3. Apparatus as claimed in claim 1 wherein a housing is filled with an inert gas as selected from the group consisting of argon, xenon and krypton.

4. Apparatus as claimed in claim 1 including first cooling means for removing heat from the anode, and second cooling means for removing heat from the cathode.

5. Apparatus as claimed in claim 4 including a source of water under pressure connected to said first cooling means and said second cooling means for removing heat from said anode and said cathode.

6. Apparatus as claimed in claim 5 wherein said first cooling means includes a plurality of parallel conduits in said anode, and means for supplying water under pressure from said

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source to said parallel conduits, and said second cooling means includes a plurality of passages in said cathode, and means for supplying water under pressure from said source to said passages.

7. Apparatus as claimed in claim 6 wherein the water from said source is under pressure from about 1,000 psi.

8. Apparatus as claimed in claim 6 wherein the passages in said cathode are gold plated to resist deposits from the pressurized water.

9. Apparatus as claimed in claim 1 including an opening in the center of said annulus, and means for supplying an inert gas to the arc through said opening.

10. Apparatus as claimed in claim 1 including means for generating a magnetic field in said cathode for controlling the rotation of spot arc emissions around the annulus.

11. Apparatus as claimed in claim 1 wherein said outwardly directed end surface of said anode is concave.

12. Apparatus as claimed in claim 1 wherein said outwardly directed end surface of said anode is substantially flat.

13. Apparatus as claimed in claim 1 wherein said outwardly directed end surface of said anode is convex.

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